

ART. XVI.—*Original Gneissoid Structure in the Cortlandt Series*; by G. S. ROGERS.

IN the course of a rather detailed investigation of the Cortlandt Series the attention of the writer was attracted by a peculiar structure occasionally occurring in these rocks, which seems to be undoubtedly of an original gneissoid character. By way of introduction a word of review about the Cortlandt Series itself may not be out of place. The rocks cover an area of about 25 square miles, and are situated just southeast of Peekskill or about 35 miles north of New York City. They constitute a small but rather complete igneous complex, containing examples of all of the main varieties from granite to peridotite. Although hitherto they have been thought of as a wholly basic group of rocks, more careful work reveals the fact that nearly a third of the whole series consists of granite, syenite, and a diorite often acid enough to be called monzonite. Pyroxenites, often chrysolitic, make up somewhat less than a third, while several varieties of norite comprise most of the remaining types. Trachyte, sodalite-syenite, gabbro, and many dike rocks are also represented, and there are moreover several contact developments of very peculiar and abnormal composition. Finally, emery has been mined for the last 30 years, chiefly along the borders of the district.

The Cortlandt Series is rather well known from the work already done on it by two eminent geologists, Professors J. D. Dana and G. H. Williams. Professor Dana* described the rocks in connection with his work on the limestone belts of Westchester County. He directed his attention especially to the origin of the rocks, giving only a brief general description of their petrographic characters. He noticed, however, that on Montrose Point several very different kinds of rock are associated in the most intricate way, generally as successive bands; and cites one case in which norite and pyroxenite are found in alternate layers of constant grain only three or four inches wide. There are also other less pronounced cases; and from these phenomena, as well as from the occasional streaked appearance of the rocks, Dana concludes that they were originally volcanic ashes or tuffs, which, on being subjected to intense local metamorphism, lost most of their bedded structure and became pseudo-massive. In his last paper, however, which is based on the revelations of the new railroad cut

* *Geological Relations of the Limestone Belts of Westchester Co., N. Y.*, this Journal (3), xx, 194. Also, *Origin of the Rock of the Cortlandt Series*, *idem* (3), xxii, 103; and *Note on the Cortlandt and Stony Point Hornblende and Augitic Rock*, *idem* (3), xxviii, 384.

through Stony Point, he abandoned his former explanation and pronounced the rocks truly igneous. In 1886 Professor G. H. Williams* published his first paper on the Series, and in it treats the rocks as unquestionably igneous. He also mentions their occasional streaked appearance, and points out that this is just what would be expected in igneous rocks which had undergone some regional metamorphism.

The present paper is therefore not the first to describe the structure, although it is the first to interpret it as originally igneous. Recognizing the existence of such an original gneissoid structure in other parts of the world, it becomes evident that Professor Dana has described several rather obvious examples of it. The northern part of Montrose Point, where these cases occur, is a complicated mixture of a biotite-augite norite† and an olivine pyroxenite, the latter lying mainly to the south and west. These varieties appear to interpenetrate very intricately, and occasionally a structure such as Professor Dana describes is to be found. The writer noticed in one case a streak, about four feet wide, of the coarse dark pink norite in a cliff of black pyroxenite. This comparatively narrow strip was coarser, if anything, than the pyroxenite, and was coarse moreover to its very edge, having thus none of the characteristics of a dike. Analyses of these two types, given below, show their great chemical differences.

It is in the various norites, however, that the structure is best shown. It may be stated first, as a general rule, that the finer grained a norite is, the simpler it is, i.e., a very fine-grained norite is composed chiefly of feldspar, with considerable hypersthene, while the coarser varieties carry in addition either hornblende or biotite and augite. The fine-grained simple norite is never found in large areas, but always as inclusions in the coarser and therefore more complex varieties. It often occurs in biotite norite, for example, as small, rounded flow-like patches, or again as streaks; or it may be banded with the coarser rock. In this case the chemical difference is not so great, as the accompanying analyses show.

A. Biotite augite norite, from Montrose Point. Analysis by M. D. Munn, for J. D. Dana, this Journal (3), xxii, p. 104,

* The principal papers are: Peridotites of the Cortlandt Series, this Journal (3), xxxi, 26; Norites of the Cortlandt Series, *idem* (3), xxxiii, p. 135 and p. 191; and Gabbros and Diorites of the Cortlandt Series, *idem* (3), xxxv, p. 438.

† The names used to denote the different rocks are, it is believed, sufficiently explicit to obviate, for the purposes of this paper, a more detailed petrographic description. The analyses given serve the purpose; Professor Williams, in the papers cited above, gives very minute descriptions should these be desired.

1881. Contains andesine, augite, hypersthene, biotite, apatite and magnetite. Symbol, II. 5.3.4. *Andose*.

B. Augite peridotite (olivine pyroxenite) from Montrose Point. Analysis by W. H. Emerson, for G. H. Williams, this Journal (3), xxxi, p. 40, 1886. Contains augite, hypersthene, hornblende, olivine, magnetite and pyrrhotite. Symbol, IV. 2.1.2.

C. Norite, from $1\frac{1}{2}$ miles south of Peekskill. Analysis by G. S. Rogers. Contains orthoclase, andesine, hypersthene, a little biotite, apatite, ilmenite and magnetite. Symbol, II. 5.3.4. *Andose*.

D. Biotite norite, 2 miles east of Montrose Point. Analysis by G. S. Rogers. Contains orthoclase, labradorite, biotite, hypersthene, apatite, ilmenite and magnetite. Symbol, II. 5.4.3. *Hessose*.

	A.	B.	C.	D.
SiO ₂	55.34	47.41	51.49	46.10
Al ₂ O ₃	16.37	6.39	20.72	18.66
Fe ₂ O ₃	.77	7.06	1.80	3.00
FeO	7.54	4.80	7.28	9.58
MgO	5.05	15.34	3.82	6.71
CaO	7.51	14.32	6.71	8.26
Na ₂ O	4.06	.69	3.70	2.57
K ₂ O	2.03	1.40	2.14	1.59
H ₂ O +	.58	2.10	.31	.18
H ₂ O -	----	----	.10	.10
TiO ₂	----	----	2.26	2.88
P ₂ O ₅	----	----	.15	.70
MnO	.40	----	.13	----
BaO	----	----	tr.	tr.
S	----	.49	.11	.18
Sum	99.65	100.00	100.72	100.51

Norms.

	A.	B.	C.	D.
or	12.2	8.3	12.2	9.4
ab	34.1	5.2	30.9	21.5
an	20.3	10.6	32.5	34.8
C	----	----	.5	----
di	14.0	47.9	----	5.0
hy	11.4	6.7	13.8	3.0
ol	5.3	8.6	2.9	15.9
mt	1.2	10.2	2.6	4.4
il	----	----	4.2	5.3
ap	----	----	.4	1.2

Now if the simpler norite be not quite so fine-grained it will not be entirely pure; and this is the case in most places. In fig. 1 the mass of the rock is a biotite-augite norite, while

the white streak is merely a finer and therefore simpler facies, containing only small amounts of biotite and augite. In one place it shows an included patch of the coarser rock. Fig. 2 shows the same relations on a smaller scale, but in better

FIG. 1.

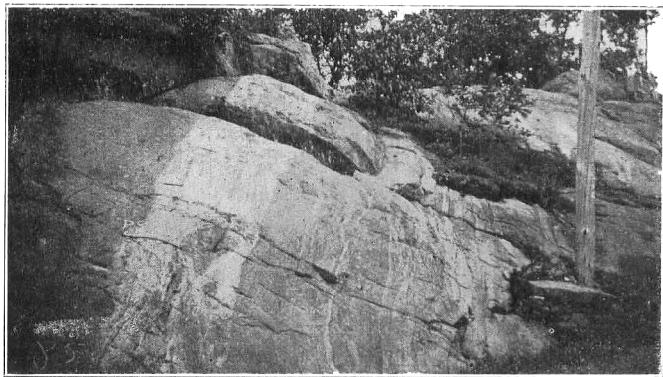
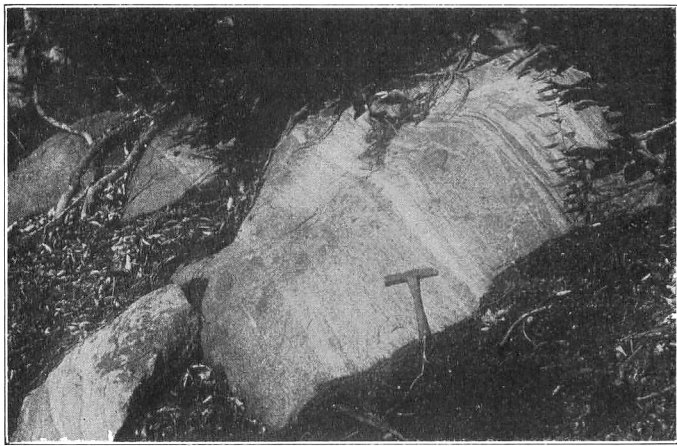


FIG. 2.



FIGS. 1, 2. Original gneissoid structure in the Cortlandt Series.

development, so that the rock might easily be mistaken for a real metamorphic gneiss. A number of other equally good instances might be shown, for the structure is quite common; but these suffice to show its general aspect. It may be added that none of the rocks of this series exhibit any great amount

of shearing; and that in all the cases examined which show this flow structure, it is absent, even in thin section. The phenomenon could not, therefore, be due to ordinary regional metamorphism.

The classic locality for this structure is on the Isle of Skye, in Tertiary gabbro, where it was first described as such by Sir Archibald Geikie and Professor Teall.* From their photographs it appears to be little, if any, better developed than in the Cortlandt. The same structure, however, has been described in wonderful perfection by Professor A. G. Högbom* from the Island of Ornö, just south of Stockholm. Here the black and white bands are narrow and numerous, and may be traced for 60–80 meters with the utmost ease. The zone in which this development occurs constitutes the periphery of an igneous (dioritic) complex. It is also found strikingly developed near Montreal; this occurrence will be described by Professor Frank D. Adams in a forthcoming work.

The explanation now accorded this phenomenon is simple and plausible. Eliminating Dana's idea of worked-over volcanic ashes, and Williams' suggestion of the ordinary regional metamorphism of igneous rocks, we are thrown back on some force concomitant in its action with the cooling of the rock. Since the several layers or streaks are always quite different in mineralogical composition, and more or less so in chemical, it is evidently a question of magmatic differentiation. It is inconceivable that the structure be due to the differentiation of a magma *in situ*—after it has reached its present position—since the differentiation is into bands which bear no definite relation to the borders of the magma; and the idea of successive intrusions—first of a light band and then of a dark—is equally inapplicable, since even when there is a sharp line of demarcation separating two bands, the individual grains seem to interlock across the line. The only remaining hypothesis, therefore, is that of the intrusion of a molten mass already heterogeneous. Professors Geikie and Teall‡ push their conclusions thus far; Mr. Harker§ goes a bit further. He appears to favor the view that the structure is due to the approximately simultaneous intrusion of two different magmas, which would give rise to a thorough interpenetration of the two. This would explain why the banded structure, which always shows evidence of flowage, is seldom straight and clear-cut. The assumption would be then that the mass must have

* On the Banded Structure of some Tertiary Gabbro on the Isle of Skye. Quar. Journ. Geol. Soc., Nov. 1894, i, 646.

† Zur Petrographie von Ornö Hufvud, Bull. Geol. Instit. Upsala, x, 150.

‡ Op. cit.

§ Natural History of Igneous Rocks, New York, 1909.

promptly begun to cool and harden while resting quietly, as otherwise the two magmas might combine to form a third and homogeneous one. Mr. Harker's alternative view is that the mass was intruded as a unit, already heterogeneous, the two different magmas having been partly mixed before intrusion. Whichever be the correct theory, it is evident that in the Cortlandt Series the simple norite magma was very small in comparison with the more complex norite magmas, since the former always appears as included bands in the others, while these latter cover extensive areas.

It is interesting to note that here, as in most of the other examples of this structure, there have been distinct changes in our conception of its significance. The old school of American geologists, of which Professor Dana was the last great disciple, were very prone to consider as worked-over sediments what are now called true igneous masses; and he therefore even adduced this structure to prove the sedimentary origin of the rocks. Dr. Williams, on the other hand, was one of the early exponents of the school which has laid great stress on metamorphic action in igneous rocks, and he accordingly passed it over without concern, as being merely an evidence of regional metamorphism. To-day we are passing—or perhaps have passed—through yet another change; Vogt, Högbom, Harker, Adams, Pirsson, Kemp and others are now, in the light of our present greater knowledge, reading into igneous action many attributes, for the manifestation of which an entirely different origin had hitherto been postulated. The formation of this original gneissoid structure is a case in point. Up to the present it has not been recognized in many localities; should it be found to be more common than is now thought, however, it may prove illuminating (as Sir Archibald Geikie suggests) in connection with some of the puzzling structures of the ancient and obscure igneous gneisses.

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